Development of an Atmospheric Climate Model with Self-Adapting Grid and Physics

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One of the most important advances needed in global climate models is the development of models that can reliably treat convection. At the present time, convection is a sub-grid process that must be parameterized. Accurate treatment during convective events requires solution of the equations of motion in a non-hydrostatic framework, while typically climate models treat only the large-scale flow, for which the simplifying assumption that the flow is hydrostatic is accurate.

This project will result in a climate model that self-adjusts the grid resolution and the complexity of the physics model to the actual atmospheric flow conditions. Calculations with the non-hydrostatic model are only performed where judged necessary by a convective instability criterion, thereby keeping computer requirements to a minimum. Horizontal grid refinement will occur throughout the physics regimes as needed to accurately predict solutions of the primitive equations. The development of a single method that solves different physics in different domains is a code-development challenge that is encountered more and more often in today's scientific-computing arena.

We plan to subdivide the computational grid into blocks to allow us to run the model in a parallel computing environment so that complex simulation can be performed within reasonable time. We expect to exploit the knowledge of solution-adaptive techniques developed earlier by members of our team to determine efficient methods for adaptation in the meteorological framework. The data structures and load-balancing techniques that make solution-adaptive methods truly scalable for this class of problems will be researched, so that the resulting code yields high performance. In addition, the ability to apply different physical models in different regimes, while maintaining scalability, will be explored.

This advanced climate model will lead to new insights into small-scale and large-scale climate interactions, which are unresolved by current uniform grid approaches.

The adaptive grid techniques will be applied to a parallel version of the NASA/NCAR Finite-Volume Community Climate Model (FVCCM), which has recently been developed jointly at NCAR and the NASA Goddard Space Flight Center (GSFC, Data Assimilation Office DAO) and parallelized at the GSFC. This model is based on the so-called Lin-Rood dynamical core that provides highly efficient algorithms for high performance computing. In order to accomplish its goal this research project will be based on four steps. These milestones will first lead to an investigation of static refinement techniques before formulating and implementing dynamic refinement criteria.

This research project is characterized by an interdisciplinary approach involving atmospheric science, computer science and mathematical/numerical aspects. The work will be done in a close collaboration between different departments of the University of Michigan, with NASA/GSFC and the National Center for Atmospheric Research (NCAR).